27450/P [P]

HAMILTON H. [1767]

Philosophical essays 176

All before p[79] wanting

Digitized by the Internet Archive
in 2018 with funding from
Wellcome Library

https://archive.org/details/b30376786

[P]
39261

Hamilton, Hugh
[1767]

# AN
# ESSAY
# ON THE
# PRINCIPLES OF MECHANICKS.

N 2

WELLCOME
LIBRARY
INSTITUTE

# AN
# ESSAY
# ON THE
# PRINCIPLES OF MECHANICKS.[*]

IN this Eſſay I mean to offer ſome Remarks on the Methods that have been commonly uſed in treating of thoſe Engines that are called the Mechanick Powers; and to give an Account of the Principles on which, I think, we may beſt explain their Nature and Manner of Acting.

---

[*] This Eſſay was read at a Meeting of the Royal Society on the 21ſt and 23th of *April*, 1765, communicated in a Letter, dated 13 *July* 1762,

The many uſeful Inſtruments that have been ſo ingeniouſly invented, and ſo ſucceſsfully executed, and the great Perfection to which the Mechanick Arts are now arrived, would naturally incline one to think that the true Principles on which the Efficacy and Operations of the ſeveral Machines depend, muſt long ſince have been accurately explained. But this is by no Means a neceſſary Inference; for, however Men may differ in their Opinions about the true Method of accounting for the Effects of the ſeveral Machines, yet the practical Principles of Mechanicks are ſo perfectly known by Experience and Obſervation, that the Artiſt is thereby enabled to contrive and adjuſt the Movements of his Engines with as

---

1762, to *Matthew Raper*, Eſq: F. R. S. of *Thorley*, in *Hertfordſhire*. *Vide* Phil. Tranſactions. Vol. LIII.——[In which ſome Improvements have been ſince made by the Author.]

as much Certainty and Succeſs as he could do, were he thoroughly acquainted with the Laws of Motion, from which theſe Principles may be ultimately derived. However, though an Inquiry into the true Method of deducing the practical Principles of Mechanicks from the Laws of Motion, ſhould perhaps not contribute much to promote the Progreſs of the Mechanick Arts, yet it is an Enquiry in itſelf uſeful, and in ſome Meaſure neceſſary; for, ſince late Authors have uſed very different Methods of treating this Subject, it may be ſuppoſed that no one Method has been looked upon as ſatisfactory and unexceptionable. I ſhould therefore wiſh to contribute towards having this Subject treated with more Accuracy than has been hitherto done.

The moſt noted Theorem in Mechanicks is this, " When two heavy Bo-
" dies counterpoiſe each other by Means
" of any Machine, and are then made

“ to move together, the Quantities of “ Motion with which one deſcends and “ the other aſcends perpendicularly will “ be equal.” An *Æquilibrium* always accompanying this Equality of Motions, bears ſuch a Reſemblance to the Caſe wherein two moving Bodies ſtop each other when they meet together with equal Quantities of Motion, that many Writers have thought that the Cauſe of an *Æquilibrium* in the ſeveral Machines might be immediately aſſigned by ſaying, that ſince one Body always loſes as much Motion as it communicates to another, two heavy Bodies counteracting each other muſt continue at Reſt, when they are ſo circumſtanced that one cannot deſcend without cauſing the other to aſcend at the ſame Time, and with the ſame Quantity of Motion; for then ſhould one of them begin to deſcend, it muſt inſtantly loſe its whole Motion by communicating it to the other. This Argument, however plauſible it may ſeem, I think is by no

Means ſatisfactory; for when we ſay that one Body communicates its Motion to another, we muſt neceſſarily ſuppoſe the Motion to exiſt firſt in the one and then in the other; but in the preſent Caſe, where the two Bodies are ſo connected that one cannot poſſibly begin to move before the other, the deſcending Body cannot be ſaid to communicate its Motion to the other, and thereby make it aſcend: But whatever we ſhould ſuppoſe cauſes one Body to deſcend, muſt be alſo the immediate Cauſe of the other's aſcending, ſince, from the Connexion of the Bodies, it muſt act upon them both together, as if they were really but one. And therefore, without contradicting the Laws of Motion, I might ſuppoſe the ſuperior Weight of the heavier Body, which is in itſelf more than able to ſuſtain the lighter, would overcome the lighter, and cauſe it to aſcend with the ſame Quantity of Motion with which the heavier deſcends; eſpecially as both their Motions, taken together, may be leſs than what the Difference of the Weights, which is here ſuppoſed to be the moving Force, would be able to produce in a Body falling freely.

However, as the Theorem abovementioned is a very elegant one, it ought certainly to be taken Notice of in every Treatiſe of Mechanicks, and may ſerve as a very good *Index* of an *Æquilibrium* in all Machines; but I do not think that we can from thence, or from any one general Principle, explain the Nature and Effects of all the Mechanick Powers in a ſatisfactory Manner, becauſe ſome of theſe Machines differ very much from others in their Structures, and the true Reaſon of the Efficacy of each of them, is beſt derived from its particular Structure.

The ſimple Mechanick Powers are uſually reckoned ſix; the Lever, Axle and Wheel, Pulley, Wedge, inclined Plane, and Screw. I ſhall conſider theſe Machines ſeparately, and ſhall explain the Nature and Property of each of them, by ſhewing from its Structure what Weight it will enable any given Force to ſuſtain.

The Lever is conſidered as an inflexible Line, void of Weight, and moveable about a fixed Point called its *Fulcrum* or Prop. The Property of the Lever, expreſſed in the moſt general Terms, is this; "When two Weights, "or any two Forces, act againſt each "other on the Arms of a Lever, and "and are in *Æquilibrio*, they will be "to each other inverſly as the perpendicular or ſhorteſt Diſtances of their "Lines of Direction from the *Fulcrum*."

This Propoſition contains two Caſes, for the Directions of the Forces may either meet in a Point or be parallel to each other. Moſt Writers begin their Demonſtration of this Propoſition with the ſecond Caſe, which ſeems to be the ſimpleſt, and from which the other may be deduced by the Reſolution of Forces. *Archimedes*, in his Demonſtration, ſets out with a Suppoſition, the Truth of which may reaſonably be doubted: For he ſuppoſes, that if a Number of equal Weights be ſuſpended from the Arm of a Lever, and at Points equidiſtant from each other, whether all theſe Points be at the ſame Side of the *Fulcrum*, or ſome of them on the oppoſite Side, theſe Weights will have the ſame Force to turn the Lever as they would have were they all united and ſuſpended from a Point which lies in the Middle between all the Points of Suſpenſion, and may be conſidered as the common Center of Gravity of all the ſeparate Weights. Mr. *Huygens*, in his *Miſcellaneous Obſervations on Mechanicks*, ſays that ſome Mathematicians have endeavoured, by altering the Form of this Demonſtration, to render its Defects leſs ſenſible, though without Succeſs. He therefore propoſed another Proof, which is extremely tedious and prolix, and alſo depends on a *Poſtulatum* that, I think, ought not to be granted on this Occaſion; it is this: "When two equal "Bodies are placed on the Arms of a "Lever, that which is furtheſt from the "*Fulcrum* will prevail and raiſe the "other up." Now this is taking it for granted, in other Words, that a ſmall Weight placed further from the *Fulcrum* will ſuſtain or raiſe a greater one. The Cauſe and Reaſon of which Fact muſt be derived from the Demonſtration that follows, and therefore this Demonſtration ought not to be founded on the ſuppoſed Self-evidence of what is partly the Thing to be proved.

Sir *Iſaac Newton*'s Demonſtration of this Propoſition is indeed very conciſe, but it depends on this Suppoſition. That when from the *Fulcrum* of a Lever ſeveral Arms or *Radii* iſſue out in different Directions, all lying in the ſame vertical Plane, a given Weight will have the ſame Power to turn the Lever from which-ever Arm it hangs, provided the Diſtance of its Line of Direction from the *Fulcrum* remains the ſame. Now it muſt appear difficult to admit this Suppoſition, when we conſider that the Weight can exert its whole Force to turn the Lever only on that Arm which is the ſhorteſt, and is parallel to the Horizon, and on which it acts perpendicularly, and that the Forces which it exerts, or with which it acts perpendicularly, on any one of the oblique Arms, muſt be inverſly as the Length of that Arm, which is evident from the Reſolution of Forces.

Mr. *Maclaurin*, in his *View of Newton's Philoſophy*, after giving us the Methods by which *Archimedes* and *Newton* prove the Property of the Lever, propoſes one of his own, which, he ſays, appears to be the moſt natural one for this Purpoſe. From equal Bodies, ſuſtaining each other at equal Diſtances from the *Fulcrum*, he ſhews us how to infer that a Body of one Pound (for Inſtance) will ſuſtain another of two Pounds at Half its Diſtance from the *Fulcrum*, and from thence that it will ſuſtain one of three Pounds at a third Part of its Diſtance from the *Fulcrum*; and going on thus, he deduces, by a Kind of Induction, what the Proportion is in general between two Bodies that ſuſtain each other on the Arms of a Lever. But this Argument, were it otherwiſe ſatisfactory, yet as it cannot be applied, when the Arms of the Lever are incommenſurable, it cannot conclude generally, and therefore is imperfect.

There are ſome Writers on Mechanicks who, from the Compoſition of Forces, demonſtrate that Caſe of the general Propoſition, relating to the Lever, in which the Directions of the Forces are oblique to each other, and meet in a Point: But I do not ſind that they have had any other Way of proving the ſecond Caſe, in which the Directions of the Forces are parallel, but by conſidering theſe Directions as making an Angle with each other, though an infinitely ſmall one, or as meeting at an infinite Diſtance; which Way of reaſoning is not to be admitted in Subjects of this Kind, where the Proof ſhould always ſhew us, directly from the Laws of Motion, why the Concluſion muſt be true, in ſuch manner that we might ſee clearly the Force of every Step from the firſt Principles down to the Concluſion, which we are prevented from doing when any ſuch arbitrary and inconſiſtent Suppoſition is introduced.

From thus conſidering the various Proofs that have been given of this fundamental Propoſition in Mechanicks, we may ſee the Reaſon why many ſubſequent Writers have appeared diſſatisſied with the former Demonſtrations, and have looked for new ones; I ſhall now propoſe two Methods of demonſtrating it, merely from the Compoſition and Reſolution of Forces. The Propoſition may be expreſſed as follows.

"When three Forces act upon an
" inflexible Line, whether ſtraight or
" crooked, and keep it in *Æquilibrio*,
" any two of them will be to each
" other inverſly as the perpendicular
" Diſtances of their Lines of Direction
" from that Point to which the third
" Force is applied."

Let the three Forces E, G, F, (Fig. 2.) act upon three Points A, B, D, in an inflexible Line; and firſt let the Directions of the Forces E and F (which act on the ſame Side of the Line) meet in the Point C. Then it is evident that the Force, which is compounded of theſe two, muſt act upon the Line A B D in the Direction of a right Line that paſſeth through the

Point C, conſequently the Force G, which ſuſtains this compounded Force, muſt be equal thereunto, and muſt act in a contrary Direction; therefore the Force G muſt act in the Direction of the Line C B. From the Point B draw B H and B K perpendicular to the Directions of the Forces E and F, and draw B M and B N parallel to theſe Directions forming the Parallelogram B M C N; then, ſince theſe three Forces are in *Æquilibrio*, they muſt be to each other reſpectively as the Sides and Diagonal of this Parallelogram to which their Directions are parallel, therefore E is to F as C M, to C N, or M B, that is (becauſe the Sides of a Triangle are as the Sines of the oppoſite Angles) as the Sine of the Angle, M B C or its alternate one, B C N to the Sine of the Angle B C M; but, making C B the *Radius*, B K is the Sine of the former Angle, and B H of the latter, therefore E is to F as B K to B H, ſo that the Forces E and F are to each other inverſly as the perpendicular Diſtances of their Lines of Direction from the Point B, on which the third Force G acts. Now to compare the Forces F and G together; from the Point A, on which the third Force acts, draw A B and A L perpendicular to the Directions of the Forces G and F, then, as was ſaid before, F is to G as M B is to C B, but M B is to C B as A B to A L; becauſe, making C A the *Radius*, A B is the Sine of the Angle M C B, and A L is the Sine of the Angle M C N, or C M B its Supplement to two right ones; therefore the Forces F and G are to each other inverſly as the perpendicular Diſtances of their Lines of Direction from the Point A, on which the third Force E acts; and thus the firſt Caſe of the Propoſition is proved, in which the Forces act againſt each other in oblique Directions.

We muſt now conſider what Parts of the Forces E and F act againſt the

Force G in Directions parallel to G C, for it is ſuch Parts only that really oppoſe the Force G, and keep it in *Æquilibrio*, and from thence we ſhall ſee what Proportion two Forces muſt have to each other when they are in *Æquilibrio*, and act in parallel Directions. Let the three Forces act upon the Points A, B and D, (Fig. 3.) let them be in *Æquilibrio*, and their Lines of Direction meet in the Point C, as in the preceding Caſe; then if the Points A, B and D, are not in a right Line, draw the Line A D meeting B C in P, and from P draw P N and P M parallel to the Directions of the Forces E and F; through the Points A and D draw Lines parallel to B C, and thro' B draw a Perpendicular to theſe Lines meeting them in H and K, from the Point M draw M O parallel to A D, and meeting B C in O. Now the three Forces E, G and F, that are in *Æquilibrio*, will be to each other reſpectively as the Sides of the Triangle C M P, as in the preceding Caſe; but the Force E, which is denoted by the Line M C, may be reſolved into two Forces acting in the Directions M O and O C, the former of theſe only urges the Point A towards D, and the latter acts in direct Oppoſition to the Force G; in like Manner the Force F, which is denoted by the Line P M, may be reſolved into two Forces acting in the Directions O M and P O, the former of which only urges the Point D towards A, and the latter acts in direct Oppoſition to the Force G; now it is evident that the Force G, which is denoted by the Line P C, is ſuſtained only by thoſe Parts of the Forces E and F, which act againſt it, in Directions parallel to B C, and are denoted by the Lines O C and P O, which, taken together, are equal to P C, for the other Parts of the Forces E and F which are denoted by M O, are loſt, being equal and contrary to each other; if, therefore, inſtead of the Forces F and E, we ſuppoſe two other Forces R and L, to act on the Points D and A, in Directions parallel to B C, and to keep the Force G in *Æquilibrio*, it follows, from what has been proved, that R and L, taken together, will be equal to G, and that theſe three Forces will be to each other reſpectively as the Lines P O, O C and P C; therefore R will be to L as (P O to O C, that is, as A M to M C, or as A P to P D, or) H B to B K, conſequently the Forces R and L are to each other inverſly as the perpendicular Diſtances of their Lines of Direction from the Point B, to which the third Force is applied. Now to compare the Forces R and G together; ſince the Forces R and L may be denoted by B H and B K, and are both together equal to G, that Force will be denoted by the whole Line K H, and therefore R will be to G as B H to K H; ſo that theſe Forces are alſo to each other inverſly as the perpendicular Diſtances of their Lines of Direction

tion from the Line of Direction of the third Force L; and thus the ſecond Caſe of the Propoſition is proved, in which the Forces act againſt each other in parallel Directions. If the Point in the inflexible Line, to which one of the Forces is applied, ſhould become a fixed Point, or *Fulcrum*, round which the Line may turn, it is evident that the other two Forces will continue in *Æquilibrio*, as they were before, and therefore the Property of the Lever, in all Caſes, is manifeſtly proved by this Propoſition.

The Center of Gravity of a Body is ſaid to be that Point which being ſuſtained, or prevented from deſcending, the Body will continue at reſt. From hence it follows, that when a Body hangs freely from a ſingle Point, and continues at reſt, its Center of Gravity will lie perpendicularly under the Point of Suſpenſion; for in that Situation only it will be ſuſtained, and can deſcend no lower.

From this Property, which agrees likewiſe to the common Center of Gravity of two Bodies, joined together by an inflexible right Line, and which may then be conſidered as one, I ſhall ſhew that their Center of Gravity is a Point in the Line that joins them together, ſo ſituated that the Diſtances of the two Bodies from it are to each other inverſly as their Weights. This Theorem concerning the Poſition of the common Center of Gravity of two Bodies, which is a very noted one in Mechanicks, I have never ſeen demonſtrated otherwiſe than by inferring it from the general Property of the Lever: But I think the Method I ſhall now propoſe of deducing it directly from the Definition of the Center of Gravity, is the moſt conciſe, as well as the moſt natural, and, beſides, it will afford us a very eaſy Way of demonſtrating the Property of the Lever.

Let the Two Bodies A and B (Fig. 4.) be joined by an inflexible right Line paſſing through their Centers of Gravity, and let them be ſuſpended from the fixed Point or Pin at P, by the Threads A P and B P, ſo that they may hang freely in ſuch a Poſition as their joint Gravity will give them. When theſe Bodies continue at Reſt, their common Center of Gravity muſt lye directly under the Point of Suſpenſion, or in the perpendicular Line P L, conſequently it muſt be at the Point C, the interſection of the Lines P L and A B; the Poſition of which Point, in the Line A B, will be determined by finding out the Proportion between the Segments C A and C B. If the inflexible Line was not interpoſed between theſe Bodies, they would move till their Threads coincided with the perpendicular Line P L; ſince therefore they are kept aſunder by this Line they muſt urge it with certain Forces in oppoſite Directions, and theſe urging

Forces muſt be equal, ſince the Line on which they act continues at reſt; and therefore the Force with which each Body urges the other in the Direction of this Line, may be denoted by the ſame Letter U, and we may denote the Weights of the two Bodies reſpectively by the Letters A and B. Now the Body A is acted upon by three Forces, *viz.* by its Weight A in the Direction P C, by the Force U, with which the other Body urges it, in the Direction C A, and by the reaction of the Pin in the Direction A P, and ſince theſe three Forces are in *Æquilibrio*, and keep the Body at Reſt, they are to each other reſpectively as the Sides of the Triangle P C A; therefore A is to U, as P C to C A. In like Manner the Body B is urged by three Forces, *viz.* its Weight B in the Direction P C, the urging Force U in the Direction C B, and the reaction of the Pin in the Direction B P, which Forces are to each other as the Sides of the Triangle P C B, therefore U is to B, as C B to P C, and therefore (*ex æquo perturbate*) A is to B, as C B to C A, conſequently the Weights of the Bodies A and B are to each other inverſly as their Diſtances from the Point C, which lies directly under the Point of Suſpenſion, and is therefore their common Center of Gravity.

When two Bodies are connected by an inflexible Line, and this Line is ſupported by a Prop, ſo that their Center of Gravity cannot deſcend, the Bodies muſt continue at Reſt, and will be in *æquilibrio*. Therefore it is eaſy to ſee how, from the Theorem now demonſtrated, we may prove the Property of the Lever in that Caſe where the Directions of the Forces are parallel; and from thence the other Caſe, in which the Directions are oblique to each other, may be deduced by the Reſolution of Forces, as is uſually done. And this is the ſecond Method by which

I ſaid the general Property of the Lever might be ſtrictly demonſtrated.

The Lever is the moſt ſimple of all the Mechanick Powers, and to it may be reduced the Balance and the *Axis in Peritrochio*, or Axle and Wheel. Though I do not conſider the Balance as a diſtinct Mechanick Power, becauſe it is evidently no other than a Lever fitted for the particular Purpoſe of comparing the Weights of Bodies, and does not ſerve for raiſing great Weights or overcoming Reſiſtances as the other Machines do.

When a Weight is to be raiſed by Means of an Axle and Wheel, it is faſtened to a Cord that goes round the Axle, and the Power, which is to raiſe it, is hung to a Cord that goes round the Wheel. If then the Power be to the Weight as the *Radius* of the Axle to the *Radius* of the Wheel, it will juſt ſupport that Weight; as will eaſily appear from what was proved of the Lever. For the Axle and Wheel may be conſidered as a Lever, whoſe *Fulcrum* is a Line paſſing through the Center of the Wheel and Middle of the Axle, and whoſe long and ſhort Arms are the *Radii* of the Wheel and Axle which are parallel to the Horizon, and from whoſe Extremities the Cords hang perpendicularly. And thus an Axle and Wheel may be looked upon as a Kind of perpetual Lever, on whoſe Arms the Power and Weight always act perpendicularly, tho' the Lever turns round its *Fulcrum*. And in like Manner, when Wheels and Axles move each other by Means of Teeth on their *Peripheries*, ſuch a Machine is really, a perpetual compound Lever: and, by conſidering it as ſuch, we may compute the Proportion of any Power to the Weight it is able to ſuſtain by the Help of ſuch an Engine. And ſince the *Radii* of two contiguous Wheels, whoſe Teeth are applied to each other, are as the Number of Teeth in each, or inverſly as the Number of Revolutions, which they make in the ſame Time; we may, in the Computation, inſtead of the *Ratio* of theſe *Radii*, put the *Ratio* of the Number of the Teeth on each Wheel; or the inverſe *Ratio* of the Number of Revolutions they make in the ſame Time.

Some Writers have thought the Nature and Effects of the Pulley might be beſt explained by conſidering a fixed Pulley as a Lever of the firſt, and a moveable Pulley as one of the ſecond, Kind. But the Pulley cannot properly be conſidered as a Lever of any Kind, for when any Power ſuſtains a Weight by Means of a Syſtem of Pullies, that Power will ſuſtain the ſame Weight if the Pullies be removed, and the Ropes be brought over the Axles on which the Pullies turned. And in this Caſe I believe no one would ſay, that theſe Axles could be conſidered as Levers.

It

If the Weight was to be raiſed up, there would, in this Caſe, be a very great Reſiſtance from the Friction of the Ropes on the Axles; and it is merely to avoid this Reſiſtance that Pullies are uſed, which move round the Axles with but little Friction. I think the beſt and moſt natural Method of explaining the Effects of the Pulley (that is, of computing the Proportion of any Power to the Weight it can ſuſtain by Means of any Syſtem of Pullies) is by conſidering that every moveable Pulley hangs by two Ropes equally ſtretched, which muſt bear equal Parts of the Weight; and therefore when one and the ſame Rope goes round ſeveral fixed and moveable Pullies, ſince all its Parts on each Side of the Pullies are equally ſtretched, the whole Weight muſt be divided equally amongſt all the Ropes by which the moveable Pullies hang. And conſequently if the Power which acts on one Rope be equal to the Weight divided by the Number of

Ropes, that Power muſt ſuſtain the Weight.

Upon this Principle, the Proportion of the Power to the Weight it ſuſtains by Means of any Syſtem of Pullies, may be computed in a Manner ſo eaſy and natural, as muſt be obvious to every common Capacity.

The Proportion which any Power bears to the reſiſting Force it is able to ſuſtain by Means of a Wedge, has has been laid down differently by different Authors, as they happened to conſider it in particular Caſes. Without examining their ſeveral Opinions, I ſhall endeavour to expreſs this Proportion in one general Propoſition, which may extend to the ſeveral Caſes in which the Wedge is applied.

Let the *Æquicrural* Triangle A B C (Fig. 5) repreſent a Wedge, whoſe Baſe or Back is A C, and Sides are the Lines,

Lines A B and C B, and whoſe Height is the Line B P, which biſects, the vertical Angle A B C and alſo, the Baſe perpendicularly in P. When a Power is applied to the Wedge, in order to overcome or remove any reſiſting Forces, it acts perpendicularly on the Back of the Wedge, and the reſiſting Forces act on its Sides, and they are always ſuppoſed to act in Directions that make equal Angles with the Sides. When the reſiſting Forces and the Power, that acts on the Wedge, are in *Æquilibrio*, the former will be to the latter, as the Height of the Wedge to a Line drawn from the Middle of the Baſe to one Side, and parallel to the Direction in which the reſiſting Force acts on that Side.

Let E and F repreſent two Bodies or two reſiſting Forces acting on the Sides of the Wedge perpendicularly, and whoſe Lines of Direction E P and F P meet at the middle Point of the

Baſe, on which the Power P acts perpendicularly, then will E P and F P be equal, let the Parallelogram E N F P be compleated, its Diagonals P N and E F will biſect each other perpendicularly in H. Now when theſe Forces (which act perpendicularly on the Sides and Baſe of the Wedge) are in *Æquilibrio*, they will be to each other as the Sides and Diagonal of this Parallelogram, that is, the Sum of the reſiſting Forces will be to the Power P, as the Sides E P and F P to the Diagonal P N, or as one Side E P to half the Diagonal P H, that is (from the Similarity of the right-angled Triangles B E P, E H P) as B P, the Height of the Wedge, to E P the Line which is drawn from the Middle of the Baſe to the the Side A B, and is the Direction in which the reſiſting Force acts on that Side.

From the Demonſtration of this Caſe, in which the reſiſting Forces act perpendicularly on the Sides of the Wedge, it appears that the Reſiſtance is to the Power which ſuſtains it, as one Side of the Wedge A B is to the Half of its Breadth A P; becauſe A B is to A P as B P is to E P.

It appears alſo from hence, that if P N be made to denote the Force with which the Power P acts on the Wedge, the Lines P E and P F which are perpendicular to the Sides, will denote the Force with which the Power P protrudes the reſiſting Bodies in Directions perpendicular to the Sides of the Wedge.

Let us now ſuppoſe, in the ſecond Caſe, that the reſiſting Bodies E and F act upon the Wedge in Directions parallel to the Lines D P and O P, that are equally inclined to its Sides, and meet in the Point P. Draw the Lines E G and F K perpendicular to D P and O P; then making P N denote the Force with which the Power P acts on the Wedge, Baſe, on which the Power P acts perpendicularly, then will E P and F P be equal, let the Parallelogram E N F P be compleated, its Diagonals P N and E F will biſect each other perpendicularly in H. Now when theſe Forces (which act perpendicularly on the Sides and Baſe of the Wedge) are in *Æquilibrio*, they will be to each other as the Sides and Diagonal of this Parallelogram, that is, the Sum of the reſiſting Forces will be to the Power P, as the Sides E P and F P to the Diagonal P N, or as one Side E P to half the Diagonal P H, that is (from the Similarity of the right-angled Triangles B E P, E H P) as B P, the Height of the Wedge, to E P the Line which is drawn from the Middle of the Baſe to the the Side A B, and is the Direction in which the reſiſting Force acts on that Side.

From the Demonſtration of this Caſe, in which the reſiſting Forces act perpendicularly on the Sides of the Wedge, it appears that the Reſiſtance is to the Power which ſuſtains it, as one Side of the Wedge A B is to the Half of its Breadth A P; becauſe A B is to A P as B P is to E P.

It appears alſo from hence, that if P N be made to denote the Force with which the Power P acts on the Wedge, the Lines P E and P F which are perpendicular to the Sides, will denote the Force with which the Power P protrudes the reſiſting Bodies in Directions perpendicular to the Sides of the Wedge.

Let us now ſuppoſe, in the ſecond Caſe, that the reſiſting Bodies E and F act upon the Wedge in Directions parallel to the Lines D P and O P, that are equally inclined to its Sides, and meet in the Point P. Draw the Lines E G and F K perpendicular to D P and O P; then making P N denote the Force with which the Power P acts on the

Wedge, P E and P F will denote the Forces with which it protrudes the reſiſting Bodies in Directions perpendicular to the Sides of the Wedge, as I obſerved before; now each of theſe Forces may be reſolved into Two, denoted reſpectively by the Lines P G and G E, P K and K F, of which G E and K F will be loſt, as they act in Directions perpendicular to thoſe of the reſiſting Bodies, and P G and P K will denote the Forces by which the Power P oppoſes the reſiſting Bodies, by protruding them in Directions contrary to thoſe in which they act on the Wedge; therefore when the reſiſting Forces are in *Æquilibrio* with the Power P, the former muſt be to the latter, as the Sum of the Lines P G and P K is to P N, or as P G is to P H, that is, as P B, the height of the Wedge, is to P D * the Line drawn from the Middle of the Baſe to one Side of the Wedge and parallel to the Direction in which the reſiſting Force acts on that Side.

---

* [*P G is to P H as P B to P D.*] The right angled Triangles P G E and P E D are ſimilar

From what has been demonſtrated, we may deduce the Proportion of the Power to the Reſiſtance it is able to ſuſtain in all the Caſes in which the Wedge is applied. Firſt, when in cleaving Timber the Wedge fills the Cleft, then the Reſiſtance of the Timber acts perpendicularly on the Sides of the Wedge, therefore in this Caſe, when the Power which drives the Wedge, is

ſimilar, having the Angle at P common to both; therefore P G is to P E as P E to P D; ſo likewiſe the rightangled Triangles P H E and P E B are ſimilar, and therefore P H is to P E as P E to P B; therefore the rectangles P G into P D and P H into P B are equal, each of them being equal to the Square of P E, conſequently their Sides are reciprocally proportional, that is, P G is to P H as P B to P D.

to the cohefive Force of the Timber, as Half the Baſe, to one Side of the Wedge, the Power and Reſiſtance will be in *Æquilibrio.*

Secondly, when the Wedge does not exactly fill the Cleft, which generally happens, becauſe the Wood ſplits to ſome Diſtance before the Wedge. Let E L F repreſent a Cleft into which the Wedge A B C is partly driven; as the reſiſting Force of the Timber muſt act on the Wedge in Directions perpendicular to the Sides of the Cleft, draw the Line P D in a Direction perpendicular to E L the Side of the Cleft, and meeting the Side of the Wedge in D; then the Power driving the Wedge and the Reſiſtance of the Timber, when they balance, will be to each other as the Line P D to P B the Height of the Wedge.

Thirdly, when a Wedge is employed to ſeparate two Bodies that lie together on an horizontal Plane, for Inſtance two Blocks of Stone; as theſe Bodies muſt recede from each other in horizontal Directions, their Reſiſtance muſt act on the Wedge in Lines parallel to its Baſe C A; therefore the Power which drives the Wedge will balance the Reſiſtance when they are to each other as P A, Half the Breadth of the Wedge to P B its Height; and then any additional Force ſufficient to overcome the Reſiſtance ariſing from the Friction of the Bodies on the horizontal Plane will ſeparate them from each other.

The inclined Plane is reckoned by ſome Writers among the mechanick Powers; and I think with Reaſon, as it may be uſed with Advantage in raiſing Weights.

Let the Line A B (Fig. 6.) repreſent the Length of an inclined Plane, A D its Height, and the Line B D we may call its Baſe. Let the circular Body

G E F be ſuppoſed to reſt on the inclined Plane, and to be kept from falling down it by a String C S tied to its Center C. Then the Force with which this Body ſtretches the String will be to its whole Weight, as the Sine of A B D the Angle of Elevation, to the Sine of the Angle which the String contains with a Line perpendicular to A B the Length of the Plane. For let the *Radius* C E be drawn perpendicular to the Horizon, and C F perpendicular to A B, and from E draw E O parallel to the String and meeting C F in O. Then, as the Body continues at Reſt and is urged by three Forces, to wit, by its Weight in the Direction C E, by the reaction of the Plane in the Direction F C, and by the reaction of the String in the Direction E O; the reaction of the String, or the Force by which it is ſtretched, is to the Weight of the Body, as E O to C E: That is, as the Sine of (the Angle E C O, which is equal to) A B D the Angle of Elevation,

tion, to the Sine of the Angle E O C, equal to S C O, the Angle which the String contains with the Line C F perpendicular to A B, the Length of the Plane.

When therefore the String is parallel to the Length of the Plane, the Force with which it is ſtretched, or with which the Body tends down the inclined Plane, is to its whole Weight, as the Sine of the Angle of Elevation, to the *Radius*, or as the Height of the Plane to the Length. And in the ſame Manner it may be ſhewn, that when the String is parallel to B D, the Baſe of the Plane, the Force with which it is ſtretched is to the Weight of the Body, as A D to B D, that is, as the Height of the Plane to its Baſe. If we ſuppoſe the String, which ſupports the Body G E F, to be faſtened at S, and that a Force, by acting on the Line A D, the Height of the Plane, in a Direction parallel to the Baſe B D, drives the inclined Plane under the Body, and by that Means makes it riſe in a Direction parallel to A D. Then, from what was proved in the third Caſe of the Wedge, it will appear, that this Force muſt be to the Weight of the Body, as A D to B D, or rather in a Proportion ſomewhat greater: If it makes the Plane move on and the Body riſe.

From this laſt Obſervation we may clearly ſhew the Nature and Force of the Screw; a Machine of great Efficacy in raiſing Weights, or in preſſing Bodies cloſely together. For if the Triangle A B D be turned round a Cylinder whoſe Periphery is equal to B D, then the Length of the inclined Plane B A will riſe round the Cylinder in a ſpiral Manner; and form what is called the Thread of the Screw, and we may ſuppoſe it continued in the ſame Manner round the Cylinder from one End to the other; and A D the Height of the inclined Plane will be every where the Diſtance between two contiguous Threads of this Screw, which is called a Convex Screw. And a Concave Screw may be formed to fit this exactly, if an inclined Plane every Way like the former be turned round the Inſide of a hollow Cylinder, whoſe Periphery is ſomewhat larger than that of the other. Let us now ſuppoſe the Concave Screw to be fixed, and the Convex one to be fitted into it, and a Weight to be laid on the Top of the Convex Screw: Then, if a Power be applied to the Periphery of this Convex Screw to turn it round, at every Revolution the Weight will be raiſed up through a Space equal, to the Diſtance between the two contiguous Threads, that is, to the Line A D the Height of the inclined Plane B A; therefore ſince this Power applied to the Periphery, acts in a Direction parallel to B D, it muſt be to the Weight it raiſes as A D to B D, or as the Diſtance between two contiguous Threads, to the Periphery of the Convex Screw; which Diſtance between two contiguous Threads is to be meaſured by a Line parallel to the Length of the Screw. If we now ſuppoſe that a Handſpike or Handle is inſerted into the Bottom of the Convex Screw, and that the Power which turns the Screw is applied to the Extremity of this Handle, which is generally the Caſe; then as the Power is removed farther from the Axis of Motion, its Force will be ſo much encreaſed, and therefore ſo much may the Power itſelf be diminiſhed. So that the Power, which, acting on the End of a Handle, ſuſtains a Weight by Means of a Screw, will be to that Weight, as the Diſtance between two contiguous Threads of the Screw, to the Periphery deſcribed by the End of the Handle. In this Caſe we may conſider the Machine as compoſed of a a Screw and a Lever, or as Sir *Iſaac Newton* expreſſes it, *Cuneus a vecte impulſus.*

Of any two or more of theſe ſimple Machines combined together, all other Machines, however complicated, are compoſed. And their Powers and Manner of acting may therefore be explained from the Principles here laid down.

FINIS.

⁂

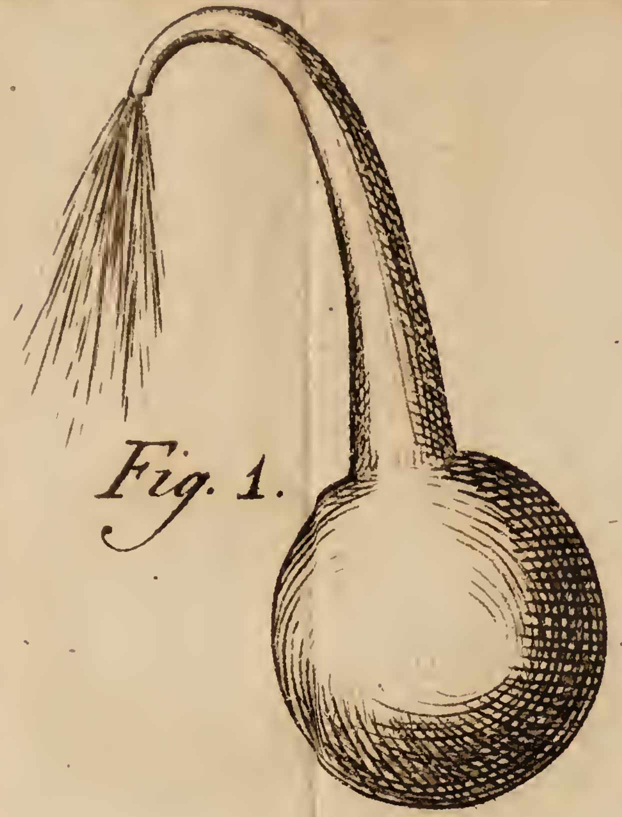

Fig. 1.

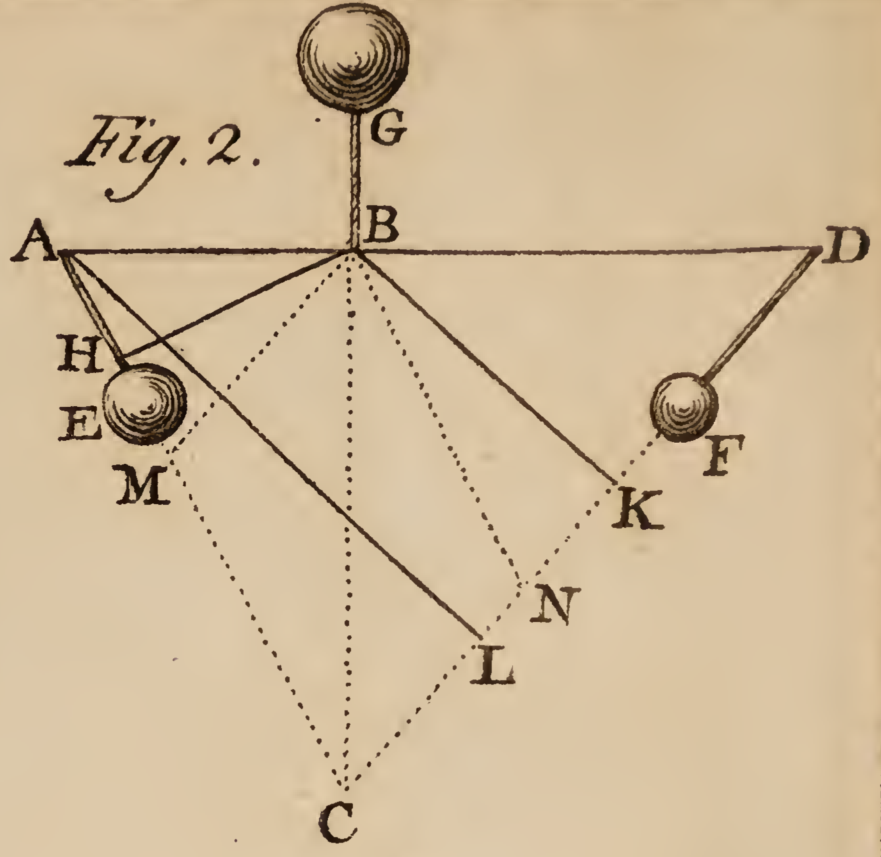

Fig. 2.

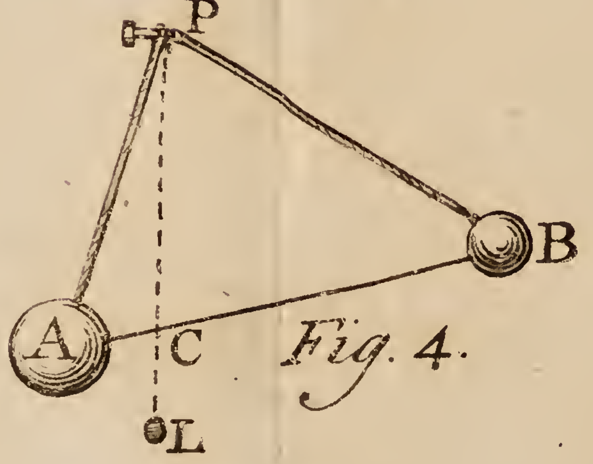

Fig. 4.

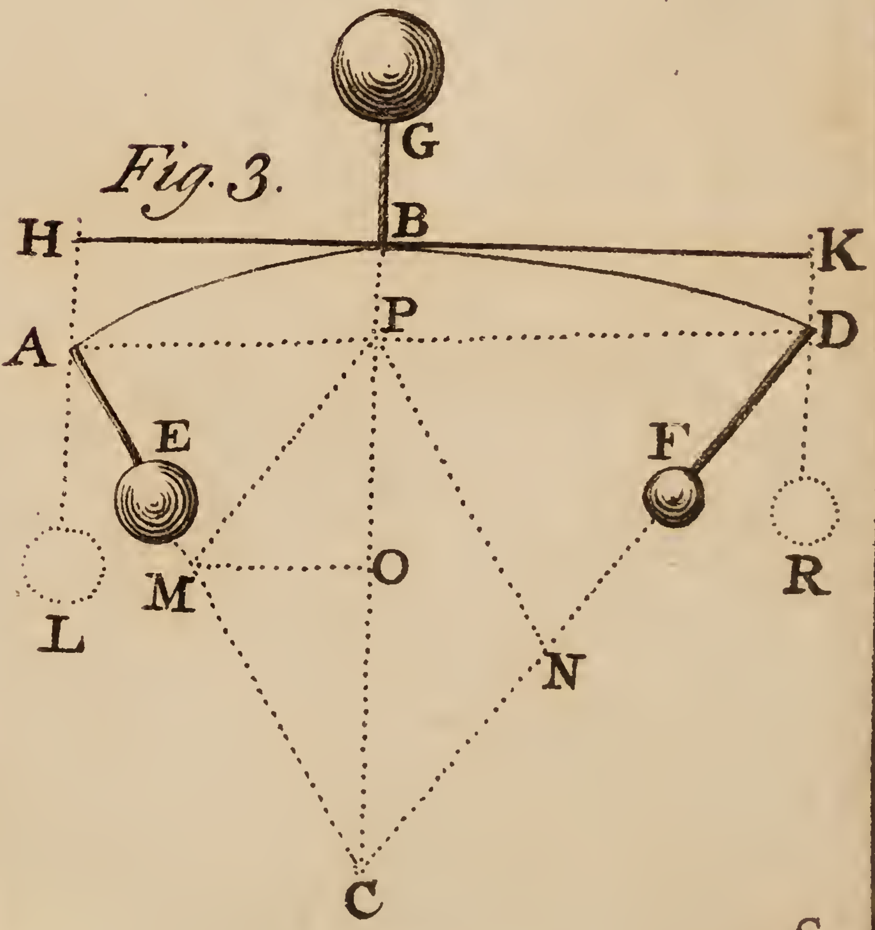

Fig. 3.

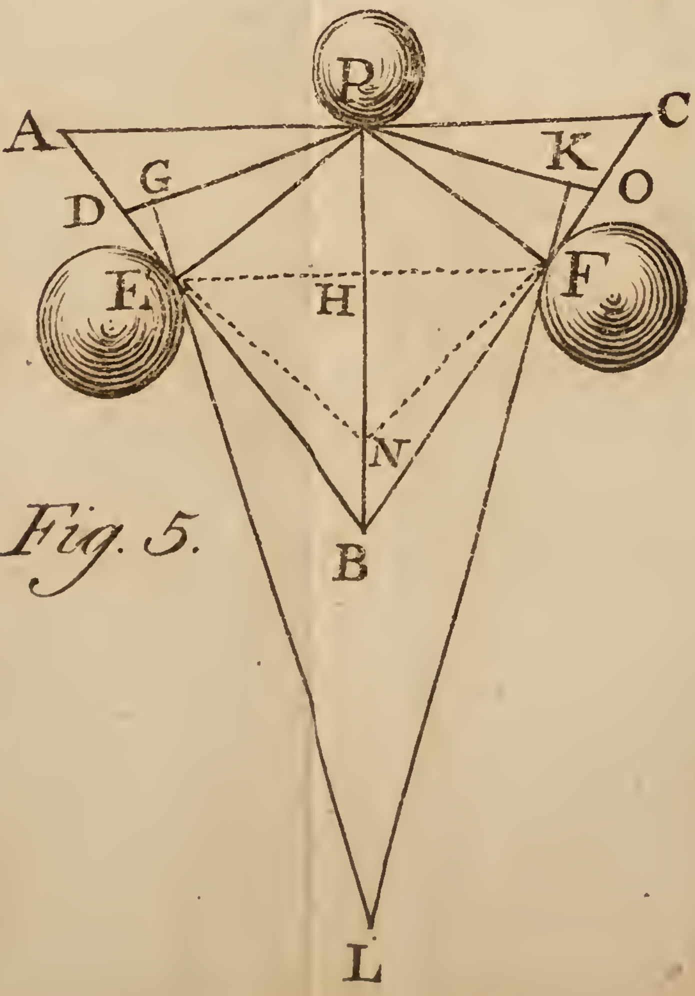

Fig. 5.

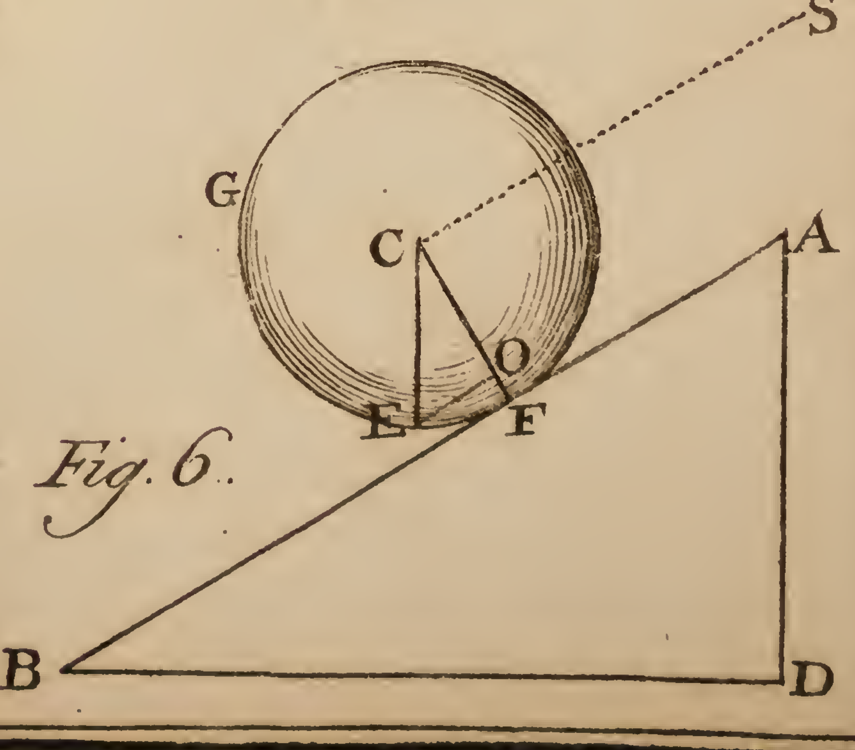

Fig. 6.

HAMILTON, H.
27450/P 1767

# Obſervations *and* Conjectures

On the Nature of the

# AURORA BOREALIS

AND THE

# TAILS of COMETS.

# OBSERVATIONS

# AND

# CONJECTURES, &c.

HAVING obſerved that ſome late Writers, who endeavour to revive the exploded Hypotheſis of an univerſal *Plenum*, bring Arguments in Favour of their Opinion from what Sir *Iſaac Newton* ſays of the Aſcent of Comet's Tails in a Direction oppoſite to the Sun; I was induced to reconſider his Account of that Matter, which, I own, never appeared ſatisfactory to me; tho' I agree intirely with him that this

Phænomenon affords a ſufficient Proof of a *Vacuum* in the Celeſtial Regions. As this is a Subject of ſome Importance in Phyſics, I ſhall, in the following Eſſay, firſt, mention ſuch Objections as occur to me againſt Sir *Iſaac*'s Opinion as to the Cauſe of the Aſcent of Comet's Tails; and then offer ſome Conjectures that may poſſibly lead to a further Knowledge of this Subject, leaving them to be confirmed or overthrown as future Obſervations and Experiments ſhall determine. For I think that Conjectures, or Hypotheſes, when rendered probable by ſome Experiments, and propoſed with Caution, may be of great Uſe by directing our Enquiries into ſome certain Channel.

That I may proceed methodically, I ſhall begin by relating the Phænomena of Comets as obſerved by *Newton*, and other accurate Aſtronomers, for I ſhall have Occaſion to refer frequently to them.

It appears that a Comet is a Kind of Planet which revolves round the Sun in a very excentric Orbit, and recedes much farther from the Sun in its *Aphelion* than any of the Planets; it is not viſible until it comes down into the Planetary Regions, and then appears ſurrounded with a denſe Atmoſphere, and from the Side oppoſite to the Sun, it emits a ſhining Train, which we call its Tail. It is at its firſt Appearance very ſhort, and encreaſes as the Comet approaches towards the Sun, and immediately after its *Perihelion*, the Tail is longeſt and moſt luminous, and then is generally obſerved to be ſomewhat bent, and to be convex towards thoſe Parts to which the Comet moves; the Convex Side being rather brighter and better defined than the Concave Side. When the Tail arrives at its greateſt Length, which in ſome Comets has been computed to be 60 or 70 Millions of Miles, it quickly decreaſes and ſoon vaniſhes entirely, about the ſame Time that the Comet itſelf ceaſes to be ſeen. The Matter of which the

Tail is formed is exceedingly rare, and ſo very pellucid that the Light of the ſmalleſt Stars ſuffers no Diminution in paſſing thro' it, for Sir *Iſaac Newton* obſerves: 'The extraordinary Rarity of Comet's 'Tails may be collected from the Stars 'ſhining thro' them; for the ſmalleſt 'Stars are obſerved to ſhine without any 'Loſs of Splendor thro' the Tails which 'are of an immenſe Thickneſs, and 'are alſo illuminated by the Light of the 'Sun.' *

Theſe are the principal Phænomena of Comets, and it is from hence we muſt deduce whatever we can know of the Subſtance of which the Tails conſiſt, or of the Reaſon why they are always thrown off from the Head of the Comet, in a Direction nearly oppoſite to the Sun. And with theſe Phænomena I propoſe to compare the Opinions which are commonly received concerning this Matter. Sir *Iſaac* tells us, there were three different Opinions about Comet's Tails, *viz.* that they were only Rays of the Sun propagated thro' the tranſparent Head of the Comet. Or that they aroſe from the Refraction of the Light in its Paſſage from the Head of the Comet to the Earth. Or, laſtly, that they conſiſted of Clouds and Vapours continually riſing from the Head of the Comet, and going off in a Direction oppoſite to the Sun. The firſt and ſecond of theſe Opinions he refutes, and adopts the third, and proves by ſeveral Arguments, that the Tail muſt conſiſt of ſome Kind of Vapour ariſing continually from the Head of the Comet. The Cauſe of its aſcending always from the Sun, he aſſigns in another Paragraph, which I ſhall now quote at Length, tranſlating it as faithfully as I can; it is as follows:

---

* Caudarum inſignis raritas colligitur ex Aſtris per eas Tranſlucentibus.—Per Immenſam vero Caudarum Craſſitudinem, Luce pariter Solis illuſtratam, Aſtra minima abſque Claritatis Detrimento tranſlucere noſcuntur. *Principia*, Page 513. Edit. 2da.

‘ The Aſcent of Tails from the Atmo-
‘ ſphere of Comets, and their Progreſs
‘ towards the Parts oppoſite to the Sun,
‘ *Kepler* aſcribes to the Action of the Rays
‘ of Light, carrying with them the Mat-
‘ ter of which the Tails conſiſt. And
‘ that ſo very thin an Air or Vapour
‘ ſhould yield to the Action of the Rays,
‘ in Spaces void of Reſiſtance, is not al-
‘ together againſt Reaſon; altho’ in our
‘ Regions, clogged with reſiſting Matter,
‘ the ſolar Rays cannot ſenſibly impel
‘ denſe Bodies. Others think that there
‘ may be ſome Particles of Matter in their
‘ own nature light, as well as ſome that are
‘ heavy, and that the Matter of the Tails
‘ is of the former Sort, and by its Levity
‘ aſcends from the Sun. But ſince the
‘ Gravity of all terreſtrial Bodies is pro-
‘ portional to their Quantity of Matter,
‘ and cannot in the ſame Body be increaſ-
‘ ed or diminiſhed, I ſuſpect that this
‘ Aſcent of the Tails ariſes rather from
‘ the Rarefaction of their Matter. Smoke
‘ aſcends in a Chimney by the Impulſe

‘ of the Air in which it floats; that Air, ‘ being rarefied by Heat and its ſpecific ‘ Gravity thereby diminiſhed, aſcends and ‘ carries the Smoke with it. Why then ‘ ſhould not the Tail of a Comet aſcend in ‘ the ſame Maner from the Sun? for the ‘ ſolar Rays do not agitate any Medium ‘ thro’ which they paſs, but in Reflection ‘ or Refraction, the reflecting Particles by ‘ that Action grow warm, and heat the ‘ ætherial Air (*auram Æthercam*) with ‘ which they are mixed, which being ra‘refied by this Heat, and the ſpecific Gra‘vity by which it tended to the Sun be‘ing thereby diminiſhed, it will aſcend ‘ and carry with it the reflecting Particles ‘ of which the Tail is formed: it con‘duces alſo to the Aſcent of theſe Va‘pours that they revolve round the Sun, ‘ and therefore endeavour to recede from ‘ it; while the Atmoſphere of the Sun ‘ either is at Reſt, or revolves more ſlowly ‘ with ſuch Motion as it can acquire from ‘ the Rotation of the Sun round its Axis. ‘ Theſe are the Cauſes of the Aſcent of

‘ the Tails in the Neighbourhood of the ‘ Sun, where the Orbit has a greater Cur‘ vature, and the Comet moves in a den‘ ſer, and therefore heavier Atmoſphere ‘ of the Sun, and then emits a Tail of a ‘ greater Length. For the Tails, which ‘ then ariſe, by preſerving their own Mo‘ tion, and at the ſame Time gravitating ‘ towards the Sun, will revolve about ‘ the Sun in *Ellipſes* juſt as their Heads ‘ do; and by that Motion will always ac‘ company their Heads and adhere to ‘ them moſt freely. For the Gravity of ‘ thoſe Vapours towards the Sun will no ‘ more cauſe the Tails to fall from the ‘ Heads to the Sun, than it will cauſe the ‘ Heads to fall from the Tails, but they ‘ muſt both, by their common Gravity, ‘ fall together to the Sun, or both toge‘ ther be retarded in their Aſcent from it: ‘ and conſequently their Gravity will not ‘ hinder the Heads and Tails of Comets ‘ eaſily to receive (from the above‘ mentioned or other Cauſes) any Poſi‘ tion whatever in reſpect to each other,

‘ or to keep this Poſition afterwards moſt
‘ freely.’ *

We find in this Account that Sir *Iſaac* aſcribes the Aſcent of Comet's Tails to their being rarer and lighter, and moving round the Sun more ſwiftly, than the ſolar Atmoſphere, with which he ſuppoſes them to be ſurrounded, whilſt in the Neighbourhood of the Sun; he ſays alſo, that whatever Poſition (in Reſpect to each other) the Head and Tail of a Comet then receive, they will keep the ſame afterwards moſt freely, and in another Place he obſerves, ‘ That the celeſtial Spaces
‘ muſt be entirely void of any Power of
‘ reſiſting, ſince not only the ſolid Bodies
‘ of the Planets and Comets, but even the
‘ exceeding thin Vapours, of which Co-
‘ met's Tails are formed, move thro' thoſe
‘ Spaces with immenſe Velocity, and yet
‘ with the greateſt Freedom.’ ‡ — I cannot help thinking that this Account is li-

---

* *Principia*, Page 514. ‡ Ibid.

able to many Difficulties and Objections, and that it ſeems not very conſiſtent with itſelf, or with the Phænomena.

I do not know that we have any Proof of the Exiſtence of a ſolar Atmoſphere of any conſiderable Extent, nor are we any where taught how to gueſs at the Limits of it. It is evident that the Exiſtence of ſuch an Atmoſphere cannot be proved merely by the Aſcent of Comet's Tails from the Sun, as that Phænomenon may poſſibly ariſe from ſome other Cauſe. However let us ſuppoſe, for the preſent, that the Aſcent of Comet's Tails is owing to an Atmoſphere ſurrounding the Sun, and ſee how the Effects ariſing from thence will agree with the Phænomena. When a Comet comes into the ſolar Atmoſphere, and is then deſcending almoſt directly to the Sun, if the Vapours which compoſe the Tail are raiſed up from it by the ſuperior Denſity and Weight of that Atmoſphere, they muſt riſe into thoſe Parts that the Comet has left, and therefore at that Time they may appear in a Direction oppoſite to the Sun. But as ſoon as the Comet comes near the Sun, and moves in a Direction nearly at right Angles with the Direction of its Tail, the Vapours which then ariſe, partaking of the great Velocity of the Comet, and being ſpecifically lighter than the *Medium* in which they move, and being vaſtly expanded thro' it, muſt neceſſarily ſuffer a Reſiſtance immenſely greater than what the ſmall and denſe Body of the Comet meets with, and conſequently cannot poſſibly keep up with it, but muſt be left bebehind, or, as it were, driven backwards by the Reſiſtance of that Medium into a Line directed towards the Parts which the Comet has left, and therefore can no longer appear in a Direction oppoſite to the Sun. And in like Manner, when a Comet paſſes its *Perihelion*, and begins to aſcend from the Sun, it certainly ought to appear ever after with its Tail behind it, or in a Direction pointed towards the Sun; for if the Tail of the Comet be ſpecifically lighter than the Medium in which it moves with ſo great Velocity, it muſt be juſt as impoſſible it ſhould move foremoſt, as it is that a Torch moved ſwiftly thro' the Air ſhould project its Flame and Smoke before it. Since therefore we find that the Tail of a Comet, even when it is aſcending from the Sun, moves foremoſt and appears in a Direction nearly oppoſite to the Sun, I think we muſt conclude that the Comet and its Tail do not move in a Medium heavier and denſer than the Matter of which the Tail conſiſts, and conſequently that the conſtant Aſcent of the Tail from the Sun muſt be owing to ſome other Cauſe. For that the ſolar Atmoſphere ſhould have Denſity and Weight ſufficient to raiſe up the Vapours of a Comet from the Sun, and yet not be able to give any ſenſible Reſiſtance to theſe Vapours in their rapid Progreſs thro' it, are two Things inconſiſtent with each other. And therefore, ſince the Tail of a Comet is found to move as freely as the Body does, we ought rather to conclude that the celeſtial Spaces are void of all reſiſting Matter, than that they are filled with a ſolar Atmoſphere, be it ever ſo rare.

But there is, I think, a further Conſideration which will ſhew that the received Opinion, as to the Aſcent of Comet's Tails, is not agreeable to the Phænomena, and may at the ſame Time lead us to ſome Knowledge of the Matter of which theſe Tails conſiſt; which I ſuſpect is of a very different Nature from what it has been hitherto ſuppoſed to be. Sir *Iſaac* ſays, the Vapours, of which the Tail of a Comet conſiſts, grow hot by reflecting the Rays of the Sun, and thereby warm and rarefy the Medium which ſurrounds them; which muſt therefore aſcend from the Sun, and carry with it the reflecting Particles of which the Tail is formed; for he always ſpeaks of the Tail as ſhining by reflected Light. But one would rather imagine, from the Phænomena, that the Matter which forms a Comet's Tail has not the leaſt ſenſible Power of reflecting the Rays of Light. For it appears from Sir *Iſaac*'s Obſervation, which I have quoted already, that the Light of the ſmalleſt Stars, coming to us through the immenſe Thickneſs of a Comet's Tail, does not ſuffer the leaſt Diminution. And yet, if the Tail can reflect the Light of the Sun ſo copiouſly, as it muſt do if its great Splendor be owing to ſuch Reflection, it muſt undoubtedly have the ſame Effect on the Light of the Stars; that is, it muſt reflect back the Light, which comes from the Stars behind it, and by ſo doing muſt intercept them from our Sight, conſidering its vaſt Thickneſs, and how exceedingly ſlender a Ray is that comes from a ſmall Star; or if it did not intercept their whole Light, it muſt, at leaſt, increaſe their Twinkling. But we do not find that it has even this ſmall Effect, for thoſe Stars that appear thro' the Tail are not obſerved to twinkle more than others in their Neighbourhood. Since therefore this Fact is ſupported by Obſervations, what can be a plainer Proof that the Matter of a Comet's Tail has no Power of reflecting the Rays of Light? and conſequently that it muſt be a ſelf-ſhining Subſtance. But the ſame Thing will further appear, from conſidering that Bodies reflect and refract Light by one and the ſame Power; and therefore if Comet's Tails want the Power of refracting the Rays of Light, they muſt alſo want the Power of reflecting them. Now, that they want this refracting Power appears from hence, if that great Column of tranſparent Matter which forms a Comet's Tail, and moves either in a *Vacuum*, or in ſome Medium of a different Denſity from its own, had any Power of refracting a Ray of Light, coming thro' it from a Star to us, that Ray muſt be turned far out of its Way in paſſing over the great Diſtance between the Comet and the Earth; and, therefore, we ſhould very ſenſibly perceive the ſmalleſt Refraction that the Light of the Stars might ſuffer in paſſing through a Comet's Tail. The Conſequence of ſuch a Refraction muſt be very remarkable, the Stars that lie near the Tail would, in ſome Caſes, appear double, for they would appear in their proper Places by their direct Rays, and we ſhould ſee their Images behind the Tail, by Means of their Rays which it might refract to our Eyes; and thoſe Stars that were really behind the Tail would diſappear in ſome Situations, their Rays being turned aſide from us by Refraction. In ſhort, it is eaſy to imagine what ſtrange Alterations would be made in the apparent Places of the fixed Stars by the Tails of Comets, if they had a Power of refracting their Light, which could not fail to be taken Notice of, if any ſuch ever happened. But ſince Aſtronomers have not mentioned any ſuch apparent Changes of Place among the Stars, I take it for granted that the Stars ſeen thro' all Parts of a Comet's Tail appear in their proper Places, and with their uſual Colours, and conſequently I infer that the Rays of Light ſuffer no Refraction in paſſing thro' a Comet's Tail. And thence

I conclude (as before) that the Matter of a Comet's Tail has not the Power of refracting or reflecting the Rays of Light, and muſt therefore be a lucid or ſelf-ſhining Subſtance.

And thus if I have argued rightly from the Phænomena, it muſt appear, that the Tail of a Comet does not conſiſt of aqueous or other Vapours, that ſhine by reflecting the Light of the Sun, but is a very rare, tranſparent and lucid Subſtance, which has no Sort of Effect on the Rays of Light that paſs thro' it, and that it is thrown off from the dark Hemiſphere of the Comet in a Direction oppoſite to the Sun, not by the ſuperior Weight and Denſity of any circumambient Medium, but by ſome other Cauſe that has not yet been diſcovered.

This ſeems to me to be all the Knowledge we can acquire of the Nature and Properties of that Matter which forms the Tails of Comets, by attending merely to the Phænomenon itſelf. But perhaps we may be able to extend this Knowledge ſomewhat further, if we could find any other Phænomenon in Nature which reſembles this of Comet's Tails, and can become acquainted with any Kind of Matter that has the ſame Properties with that of which they are formed. Now I have often obſerved a Phænomenon that, I think, very ſtrongly reſembles the Tail of a Comet, both in its Appearance, and in the Nature of its Subſtance. We frequently ſee a very rare, tranſparent, and lucid Subſtance thrown off, in a Direction nearly oppoſite to the Sun, from the dark Hemiſphere of the Earth, and principally from the more Northern and colder Regions of our Atmoſphere. This Appearance is ſo luminous that it has been from thence called the *Aurora Borealis*; it is now ſo common and well known that I ſhall not deſcribe it particularly, and will only take Notice of thoſe Circumſtances in which it chiefly reſembles a Comet's Tail. Thoſe Northern Lights never appear,

pear, at leaſt in any remarkable Degree, ſoon after Sun-ſet or before Sun-riſe, tho' it may be then dark enough to make them viſible, but generally from about ten o'Clock at Night till one in the Morning; and the very long Streams of Light, which iſſue frequently from the Northern Parts of our Atmoſphere, ſeem ſtill to tend towards the Zenith of that Place where the Spectator is, and ſometimes get beyond the Zenith, and appear to the Southward of it; which ſhews that theſe Streams of Light tend towards the Vertex of the Earth's Shadow, that is, towards the Part of the Heavens which is oppoſite to the Sun. From the great Length of theſe Streams of Light, which ſeem always moving upwards, we may conclude that they extend to a great Height in the Atmoſphere, and probably riſe far above it. For by the Accounts we have of an *Aurora Borealis*, obſerved in *England* on the Sixth of *March*, 1716, it was viſible from the Weſt Side of *Ireland*, to the Confines of *Ruſſia* and *Poland*, and probably farther to the Eaſt; ſo that it extended at leaſt over thirty Degrees of Longitude, and from about the fiftieth Degree of Latitude over almoſt all the North of *Europe*, and at all Places it exhibited the ſame Appearances, nearly at the ſame Time. ‡

Now this great Body of luminous Matter which appears in an *Aurora Borealis*, being ſo very extenſive, and ſometimes ſo very bright, muſt be viſible to a Spectator placed at a conſiderable Diſtance from the Earth, and ſhaded from the Sun's Light; and ſuch a Spectator would then ſee the Earth attended by a Train of Light in the Form of a Tail. It would probably appear ſmall in Proportion to the Earth's Diameter, it would ſeem unſteady, changeable in its Shape, and of a ſhort Continuance; but whilſt it laſted, it muſt, both in its Direction, and in the Nature and Appearance of its Light, very much reſemble the Tail of a Comet. And if ſuch a Spectator was to obſerve the Earth for a Year, he might perceive a further Reſemblance in this Reſpect between the Earth and a Comet; for as the Tail of a Comet appears only a ſhort Time before and after its *Perihelion*, ſo he would ſee this luminous Matter riſe from the Earth frequently whilſt it was moving from the Autumnal to the Vernal Equinox, thro' the Half of its Orbit that is neareſt to the Sun, and very ſeldom during the other Part of the Year, for we rarely ſee an *Aurora Borealis* in the Summer Months. Thus we find that the Matter of an *Aurora Borealis* and that of a Comet's Tail are very like each other in their Appearance, and in their Situation, with Reſpect to the Sun and the Bodies from which they flow. And if we examine further, we ſhall find that they have exactly the ſame Properties; for the Matter of which the *Aurora Borealis* conſiſts is not only very rare, tranſparent and lucid, but is alſo found to have no Sort of Effect on the

---

‡ Phil. Tranſ. No. 347.

Rays of Light which paſs thro' it. This I have often obſerved, and particularly at one Time when there appeared here an *Aurora Borealis*, § which for its Extent, for the Quantity, Brightneſs and Steadineſs of its Lights, was the moſt remarkable one I ever ſaw; ſome Parts of it appeared like very denſe white Clouds, illuminated by a full Moon, but with a more vivid Brightneſs; and yet thro' one of the denſeſt and whiteſt of theſe Clouds, I could plainly ſee the ſmalleſt Star in the *Pleiades*, and could not perceive that its Splendor was at all diminiſhed, or that it even twinkled more than it did before this lucid Matter was interpoſed, which, as it moved with a quick tremulous Motion, muſt have at leaſt increaſed the Twinkling of the Stars, if it had any Sort of Effect on the Rays which paſſed thro' it. Since then the Matter of a Comet's Tail, and that of the *Aurora Borealis* are alike in their Appearance, and agree alſo in their Properties,

---

§ *October* 16th or 17th, 1763.

perties, we have ſome Reaſon to ſuppoſe that they are Subſtances of the ſame Kind.

Having gained this Step, we may go on in our Enquiries, and try if any other Subſtance, that we are better acquainted with, has the ſame Properties with the Subſtance of which Comet's Tails and the *Aurora Borealis* are formed. It is now well known that our Atmoſphere abounds with electric Matter, which is more or leſs contained in all Bodies; this Matter is never viſible but whilſt it is paſſing from one Body to another, thro' the Air or a *Vacuum*, it then appears to be a very rare, ſubtile, ſhining Subſtance. We often ſee it flaſhing from one Cloud to another, or into the Earth, with great Velocity and Brightneſs, and then we give it the Name of Lightning; and in the ſame Manner when we bring our Finger near a Bar of Iron ſtrongly electrified, we ſee very bright Sparks iſſue from it to our Finger. It ſeems that Air, in its common State of

Condenſation, reſiſts the Egreſs of the electric Matter from Bodies in which it is accumulated, eſpecially if they are round and ſmooth, and when it forces its Way it ſeems to come out, as it were, all at once, and in a very condenſed State, and therefore it appears very bright. But if the Air be conſiderably rarefied, its Reſiſtance is thereby greatly leſſened, and the electric Matter cannot be accumulated in a Body ſurrounded by ſuch Air, for in that Caſe, as faſt as it is communicated to the Body it will iſſue out from various Parts of it in ſmall Streams of a faint Light, as will appear from ſome Experiments I ſhall have Occaſion to mention preſently.

Now ſince a ſolid Body and a Cloud, when electrified in denſe Air, will both diſcharge their Fire in the ſame Manner, that is, ſuddenly and in bright Sparks or large bright Flaſhes, we muſt conclude, from Analogy, that when they are both electrified in Air much rarefied, they will then likewiſe diſcharge their Fire in the ſame Manner, and conſequently that an electrified Cloud, raiſed into the higher and rarer Parts of the Atmoſphere, will diſcharge its Fire in continued Streams of faint Light. And as we ſometimes ſee faint Flaſhes of Lightning in a Summer Evening after Sun-ſet, tho' no Clouds appear; ſo if the Vapours which riſe into the higher Part of the Atmoſphere, tho' not formed into Clouds, carry up with them the electric Matter, they muſt diſcharge it in continued Streams of faint Light, juſt as a Cloud would do; and thoſe Streams of Light in the higher Parts of the Atmoſphere muſt exactly repreſent to us the Appearance of an *Aurora Borealis*. Any one will readily perceive a ſtrong Reſemblance between the *Aurora Borealis* and the electric Fire diſcharged from a Body in rarefied Air, who will make the following Experiments.

Let the Air be almoſt exhauſted out of a Glaſs Globe or Cylinder, and let it be turned by a Machine and rubbed as uſual; the electric Fire will then appear in the Inſide of the Globe, ſhooting out in various Branches of faint Light, croſſing each other in all Directions, and this Light will ſometimes appear tinged with different Colours; when the Air is very much rarefied, the Light appears white, and grows more of a purple Colour as more Air is admitted into the Globe. [A] I found this Experiment ſucceed beſt when I held in my Hand the Cuſhion with which the Globe was rubbed, and preſſed it ſometimes cloſely and ſometimes ſlightly to the Globe. I found that a like Appearance might alſo be exhibited by the following Experiment. A Cylinder 20 Inches high, and about five in Diameter, having a pretty thick Braſs Wire put thro' the Top, was

---

(A) This Experiment was firſt made by Mr. *Hawkſbee*, and has ſince been often repeated; and I find that the *Aurora Borealis* has of late been generally ſuppoſed to be an electrical Phænomenon, though I have not met with any Attempt to prove that it is ſo.

was almoſt exhauſted, then being myſelf electrified, I moved my Finger towards the Top of the Wire, and immediately I ſaw every Spark that came from my Finger divided into a Multitude of ſmall Streams of Light iſſuing from the Wire at right Angles to it, and in different Directions. When I took hold of the Wire I could ſee but little Light in the Cylinder, ſo found it was neceſſary to keep my Finger at a ſmall Diſtance, and let the electric Matter come to the Wire in ſucceſſive Sparks. I thought the Lights that iſſued from the Wire were brighteſt when it was oiled, and when the Air was about 30 Times rarer than the outward Air. Several Perſons almoſt as ſoon as they ſaw the electric Lights compared them to the Appearance of the *Aurora Borealis*; and certainly theſe two Phænomena reſemble each other entirely, both in the Colours of their Light, and in the Quickneſs of their Motions. For when the Air in the Glaſs-Globe was very much rarefied, the electric Lights appeared very white, and became more of a purple Colour as more Air was admitted into the Globe; juſt ſo the long Streams of Light in the *Aurora Borealis* are very white on their upper Parts, where the Air about them is much rarefied, and are often of a purple Colour on their lower Parts, which are in denſer Air. And as in the Globe the electric Lights appear in greater Abundance when the Air has a particular Degree of Denſity than in other Caſes; ſo the quick Appearing and Diſappearing of the Streams of Light in the *Aurora Borealis* may poſſibly ariſe from a Charge of Denſity in the higher Parts of the Atmoſphere. For where the Air is ſo very thin it may be ſubject to very ſudden Condenſations and Rarefactions, occaſioned by the Motion of the Winds, and I have obſerved thoſe Lights to appear and diſappear more quickly in a windy Night than when it was calm; though their Courſe or Direction was no ways influenced by the Wind.

But the electric Matter appears to be of the ſame kind of Subſtance which forms the *Aurora Borealis*, and the Tails of Comets, by its having alſo that remarkable Property of letting the Rays of Light paſs thro' it, without having any Sort of Effect upon them. And this I found by ſeveral Experiments, for I obſerved that ſmall Rays of Light, paſſing over ſharp Points, and by the Edges of Knives, from whence the electric Matter iſſued abundantly, were affected in the very ſame Manner as when theſe Points and Edges were not electrified. Having provided a large Pane of Glaſs properly coated on both Sides with thin ſheet Lead, I made two ſmall Holes in the Lead, oppoſite to each other, for a Ray of Light to paſs thro'; and I found this Ray was no more refracted in its Paſſage thro' the Holes, when one Side of the Glaſs was electrified *plus*, and the other *minus*, than it was before the Glaſs was electrified at all, or after the electric Matter was diſcharged, which ſhews that the Accumulation, or the Abſence of this

Matter no way contributed to encreaſe or diminiſh the refractive Power of the Glaſs. I found that when Water was electrified, no Change was made either in its Power of refracting or reflecting the Rays of Light.

I made many other Experiments of the ſame Kind, too tedious to deſcribe, and they all led me to conclude that the electric Matter had no Sort of Effect on the Rays of Light that paſſed thro' it. Since then the electric Matter ſeems to be of the ſame Nature with that which forms the *Aurora Borealis*, and abounds much in the Atmoſphere, and, when it gets into the rarer Parts of it, will, by its known Properties, exhibit to us an Appearance like that of the *Aurora Borealis*, we muſt acknowledge it to be a Cauſe really exiſting, and ſufficient to explain this Phænomenon, and therefore we may aſcribe the Appearance of an *Aurora Borealis* to the Riſing of the electric Matter into the upper Regions of the Atmoſphere. The following Obſervation will ſerve further to confirm this Opinion. In our Summer Months, when the electric Matter is frequently diſcharged from the lower Clouds in Lightning, and ſo returns to the Earth, we ſcarce ever ſee an *Aurora Borealis*; but at other Times, when it is not uſually diſcharged in Lightning, it may riſe higher into the Atmoſphere, and will occaſion more frequent Appearances of this Kind. And this probably is the Reaſon why theſe Appearances are more frequent in cold than in warm Climates, the former being leſs ſubject to Storms of Thunder and Lightning than the latter. In Countries that lie far to the North, the *Aurora Borealis* is ſaid to ſhine much brighter than with us, and to appear almoſt every Night.

As the preceding Conſiderations ſeem to make it probable that the Tails of Comets conſiſt of the ſame Kind of Subſtance which forms the *Aurora Borealis*, and that this is no other than the electric Matter;

I ſhall aſſume this as a Principle, and try if I can from thence account, in ſome Meaſure, for the Phænomenon of Comet's Tails, and in doing this I ſhall have an Opportunity of making ſome Obſervations which may ſerve to ſhew a further Reſemblance between thoſe three Subſtances that I have compared together. The Earth, and all Bodies near it, contain more or leſs of the electric Matter, and tho' it may be accumulated in ſome Bodies, and diminiſhed in others, we cannot be ſure that any Body may be totally deprived of it, but on the contrary have great Reaſon to think it can neither be increaſed nor diminiſhed in any Body beyond a certain Degree; we muſt therefore ſuppoſe that it is contained in all Bodies in our ſolar Syſtem. Some Bodies, ſuch as Glaſs, Amber and others, that are called *Electrics*, attract and retain this Matter more ſtrongly than thoſe do which are called *Non-Electrics*, for an electric Body will draw this Matter from one that is not electric, againſt which it is rubbed, and it will alſo ſtop the electric Matter in its Progreſs from one Body to another, and therefore an electric Body is called a *Non-conductor*, in Oppoſition to other Bodies thro' which the electric Matter readily paſſes. But we find that any Body, even the moſt electric, if ſufficiently heated, will become a *Conductor*, or will let the electric Matter paſs from it very eaſily, and therefore we conclude that Heat diſpoſes all Bodies readily to part with the electric Matter they contain, and we have an Inſtance in the *Tourmalin* Stone that ſome Bodies will always throw off an electric Matter merely by being heated. Now when a Comet comes down towards the Sun, from Regions of extreme Cold, and begins to acquire ſome Degree of Heat, it will, like other Bodies, be diſpoſed to part with the electric Matter, which it may poſſibly contain in great Abundance, and this Matter, when thrown off, will exhibit to us the Appearance of a ſhining Train, as it does in the *Aurora Borealis*; and as the Comet comes to its *Perihelion*, and the

Heat increaſes, this Matter will iſſue more abundantly, and the Train or Tail will increaſe in Length, till upon the Comet's receding from the Sun the Heat will decreaſe, and this Matter being pretty much exhauſted, the Tail will be contracted in its Dimenſions, and at length will be too far removed, and grow too faint to be obſerved.

As a Comet is expoſed to vaſt Extremes of Heat and Cold, Light and Darkneſs, we may well ſuppoſe it to be uninhabited, and if ſo, it is not neceſſary that it ſhould turn different Sides to the Sun, but may always keep the ſame Face towards it, as the Moon keeps the ſame Face towards the Earth, and indeed it muſt do ſo if its Figure be that of an oblong Spheroid. Now the electric Matter which riſes from the Earth goes off into the colder Regions of the Atmoſphere, and in a Direction nearly oppoſite to the Sun, and I believe we have no Inſtance of what we call the the *Aurora Borealis* appearing between the

Tropicks. Why then ſhould not this Matter take the ſame Courſe in its Progreſs from the Head of the Comet, and fly off from its dark Hemiſphere, where its Atmoſphere is colder and clearer, and where the Vapours are thin, and, riſing more gradually, will give it an Opportunity of riſing along with them; whilſt on the other Hemiſphere, which is expoſed to the Sun, the Vapours muſt riſe very thick, and form Clouds which may intercept the electric Matter in its Progreſs, and collecting it together may return it back to the Head of the Comet in Lightning, as our Clouds in hot Countries return their electric Matter into the Earth. Beſides as we find that the electric Matter paſſes off from a Body where it is rough or pointed, much more readily than where it is round and ſmooth, ſo it is poſſible that the Hemiſphere of the Comet, which is turned from the Sun, may be ſo formed as to part with the electric Matter more readily than the other, which is turned towards the Sun, and in whatever Direction the electric Matter is thrown off from any Body, we find it continues to move with immenſe Velocity, as I obſerved in the Streams of electric Matter which iſſued from the Wire in the exhauſted Receiver. I obſerved alſo that theſe Streams did not grow much thicker as they advanced in their Courſe, either in the exhauſted Globe or cylindrical Receiver; nor did they ſeem diſpoſed to expand themſelves into the Space that ſurrounded them, but went ſtraight forward, juſt as a Ray of ſolar Light would do. And thus the Matter which iſſues from a Comet proceeds in the ſame Direction in which it is thrown off, and forms that large Column, which we call the Tail; and we ſee that the Matter of which the Tail conſiſts has very little or no Diſpoſition to expand itſelf into the ſurrounding Spaces; for the Tail is not much broader towards the End than near the Head of the Comet. This I think is a moſt extraordinary Property, both of the electric Matter and of that which forms a Comet's Tail, and which a further Argument for concluding them to be of the ſame Nature, for they both fly off from the Body, in which they are, with great Velocity, which ſeems to argue a repulſive and expanſive Force, and yet they proceed as the Rays of Light do without expanding themſelves laterally into the Spaces thro' which they paſs.

And this remarkable Property ſeems well worth attending to, in all our Enquiries concerning the electric Matter. At preſent we are ſo little acquainted with the true Nature of it, and ſo ignorant of the Subſtance which forms the Body of the Comet, that it is not to be expected, we ſhould be able to ſay how it can furniſh ſuch a vaſt Quantity of this electric Matter, or to aſſign with Certainty the Reaſon why the Tail of a Comet is thrown off from its dark Hemiſphere in a Direction oppoſite to the Sun, rather than in any other Direction. Future Experiments and Obſervations will either confirm theſe Conjectures of mine, or ſuggeſt others more probable; but now we can only argue by Analogy from the riſing of the electric Matter thro' the colder Regions of our Atmoſphere in the *Aurora Borealis*, that the ſame Effect will take Place in the Atmoſphere of a Comet, and from the ſame Cauſe, whatever that may be.

Sir *Iſaac Newton* obſerves that the Tail of the Comet which came to its *Perihelion* on the eighth of *December*, 1680, appeared about the Middle of *January* following to be bent into a Curve. Now as the Tail was convex towards thoſe Parts which the Comet moved, this Bending might ſeem to ariſe from its meeting with ſome reſiſting Matter; but this Curvature was much leſs than what would ariſe from a reſiſting Matter denſer than the Tail, and whoſe ſuperior Gravity would be able to raiſe it up from the Sun; for he tells us that on the 5th of *January*, when the Tail was 40 Degrees long, its Chord, or a Line drawn from the Head of the Comet to the Extremity of its Tail, made an

Angle of only 8 Degrees with a great Circle paſſing thro' the Sun and Comet. But that this Curvature was not owing to any reſiſting Matter appears from hence, that the Tail muſt be bent into a Curve tho' it met with no Reſiſtance; for it could not be a right Line, unleſs all its Particles were projected in parallel Directions, and with the ſame Velocity, and unleſs the Comet moved uniformly in a right Line. But the Comet moves in a Curve, and each Part of the Tail is projected in a Direction oppoſite to the Sun, and at the ſame Time partakes of the Motion of the Comet; ſo that the different Parts of the Tail muſt move on in Lines which diverge from each other; and a Line drawn from the Head of a Comet to the Extremity of the Tail will be parallel to a Line drawn from the Sun to the Place where the Comet was, when that Part of the Tail began to aſcend, as Sir *Iſaac* obſerves; and ſo all the Chords, or Lines drawn from the Head of the Comet to the intermediate Parts of the Tail, will be reſpectively parallel to Lines drawn from the Sun to the Places where the Comet was when theſe Parts of the Tail began to aſcend. And therefore, ſince theſe Chords of the Tail will be of different Lengths, and parallel to different Lines, they muſt make different Angles, with a great Circle paſſing thro' the Sun and Comet, and conſequently a Line paſſing thro' their Extremities will be a Curve.

It is obſerved that the convex Side of the Tail which is turned from the Sun is better defined, and ſhines a little brighter than the concave Side. Sir *Iſaac* accounts for this by ſaying, that the Vapour on the convex Side is freſher (that is, has aſcended later) than that on the concave Side, and yet I cannot ſee how the Particles on the convex Side can be thought to have aſcended later than thoſe on the concave Side which may be nearer to the Head of the Comet. I think it rather looks as if the Tail, in its rapid Motion, met with ſome ſlight Reſiſtance juſt ſufficient to cauſe a ſmall Condenſation in that Side of it which moves foremoſt, and which would occaſion it to appear a little brighter and better defined than the other Side; which ſlight Reſiſtance may ariſe from that ſubtile Æther which is ſuppoſed to be diſperſed thro' the celeſtial Regions, or from this very electric Matter diſperſed in the ſame Manner, if it be different from the Æther. Here I muſt obſerve that the convex Side of the Tail, which is turned from the Sun, being brighter than the other Side, affords an additional Argument in Favour of what I have aſſerted, that the Tail does not ſhine by reflecting the Sun's Light. And this leads me to ſay ſomething of that luminous Quality which we obſerve in the electric Matter, and by which I ſuppoſe the Tails of Comets to ſhine.

The Writers on Electricity tell us that the electric Matter carries off from Bodies certain ſubtile Particles of a ſulphurous inflammable Nature, which it kindles as ſoon as they are diſengaged from the Body, and thence it ſhines. And this Account is proved from its inflaming other Bodies, ſuch as warm Spirits, and from that ſulphurous Smell which always attends the electric Matter, and which any one will perceive from his Hand, if he receives the electric Sparks on it for ſome time, and the ſame Smell is more ſtrongly perceived in Places that have been ſtruck by Lightning. Now theſe inflammable Vapours which often abound in the Air, being carried up by the electric Matter, and kindled in the higher Parts of the Atmoſphere, will cauſe it to ſhine and appear to us in the *Aurora Borealis.* That the electric Matter can kindle the inflammable Particles that it carries off from Bodies, in Air highly rarified, or even in *vacuo*, appears from its ſhining in the upper Part of the Barometer, in which is the moſt perfect *Vacuum* we can make.

But perhaps it may be ſaid, that without having recourſe to the electric Matter, we might ſuppoſe the Comet or a great Part of it, to conſiſt of ſome very combuſtible Matter which may take fire by a ſmall Degree of Heat, and blaze out in ſuch Abundance as to occaſion the luminous Appearance we call the Tail. And this Hypotheſis may appear at firſt Sight more natural and probable than the one I have ſuggeſted; yet I imagine it will not be found ſo, if we examine it attentively. For if the Comet were to take fire and blaze out as burning Bodies do with us, the elaſticity of the Flame might indeed raiſe it to ſome Diſtance from the Body of the Comet, but then it would riſe equally on all Sides, or rather to a greater Height on the Side next the Sun, where the Heat is greateſt. And a Flame of this kind could not be carried up in a Direction oppoſite to the Sun, unleſs it were by the ſuperior Denſity and Weight of ſome ſurrounding Medium which gravitates towards the Sun; juſt as we find the Flame of burning Bodies is raiſed upwards by the Preſſure of the ſurrounding Air. But I have ſhewn, in the former Part of this Eſſay, that a Medium denſer and heavier than the Tail muſt reſiſt and retard its Motion much more than that of the Comet, and therefore could never permit the Tail to move foremoſt as it ſometimes does, but muſt cauſe it always to fall behind, and conſequently to appear as directed towards the Sun when the Comet has paſſed its *Perihelion*, and is retiring from the Sun. So that in order to account for the conſtant Aſcent of this luminous Matter in a Direction oppoſite to the Sun, we muſt have recourſe to ſome Medium that has no ſenſible Gravity, and that is apt to move in ſome particular Direction from the Body in which it is, and with ſuch Velocity as to carry the burning Matter to a vaſt Diſtance from the Comet before it is entirely conſumed. Now I believe we do not know of any Medium um that has theſe Properties except that which we call the electric Matter. For it ſeems no more affected by the Force of Gravity than the Rays of Light are, and when it moves freely it is apt to go on in the Direction, in which it ſet out, as I obſerved before, and then it moves with ſuch a Velocity as we cannot meaſure, for it has been found to paſs thro' a Wire two Miles and a half in Length, as it were, inſtantaneouſly. This Medium therefore ſeems not only capable of kindling ſuch ſubtile inflammable Particles as it meets with in the Comet, but alſo of carrying them off, before they are conſumed, to the vaſt Diſtance to which the Tail ſometimes extends.

Where the inflammable Particles are quite conſumed, the Tail of the Comet muſt end; and the electric Matter will afterwards be inviſibly diſperſed thro' the planetary Regions, where it may be gathered up by the Planets in their Courſes round the Sun. For ſince we find this kind of Matter placed in all Bodies by the Wiſdom of Providence, we muſt conclude it is neceſſary for carrying on the ſeveral Operations of Nature; and we know it is very apt to eſcape from Bodies by its great Subtilty and repelling Force. We ſee it riſes from the Earth into the Atmoſphere, and is probably going off from thence when it appears in the *Aurora Borealis.* In like Manner it may fly off from the other Planets, and be continually expanding itſelf from the Center of our Syſtem beyond the Orbit of *Saturn.* So that it may be neceſſary it ſhould be brought back again and diſperſed among us by the Comets. And it ſeems to me more probable that Comets were intended for this Uſe, than for that of ſupplying the Planets with Moiſture, as as Sir *Iſaac Newton* thought. His Opinion was founded on a Suppoſition that all Vegetables have their Growth and Increaſe entirely from Water, and that ſince they do not turn again into

Water but into Earth, there muſt be a continual Decay of Moiſture, and therefore a freſh Supply of it muſt be neceſſary from time to time.* But this Suppoſition does not ſeem to have been ſufficiently grounded on Experience. For, ſince Sir *Iſaac* wrote, Dr. *Woodward*, an ingenious Phyſician, made ſeveral Experiments on Water and Vegetables growing from it. He ſhews that all Water contains an earthy Matter, and concludes: 'It is evident, that Water is not 'the Matter that compoſes vegetable Bo'dies; but is the Agent that conveys that 'Matter to them, that introduces and 'diſtributes it to the ſeveral Parts for 'their Nouriſhment. Where the proper

---

* Nam Vegetabilia omnia ex Liquoribus *omnino* creſcunt, dein magna ex parte in Terram aridam per Putrefactionem abeunt, & Limus ex Liquoribus putrefactis perpetuo decidit. Hinc moles Terræ aridæ indies augetur, & Liquores, niſi aliunde augmentum ſumerent, perpetuo decreſcere deberent, ac tandem deficere.

*Principia*, Pag. 515. Edit. 2da.

‘ terreſtrial Matter is wanting, the Plant ‘ is not augmented, tho’ never ſo much ‘ Water aſcends into it.’† This is alſo the Opinion of Dr. *Boerhaave*, and he affirms from his own Experience, that pure elementary Water cannnot, by repeated Diſtillations, or otherwiſe, be converted into Earth.‡ So that there ſeems to be no Neceſſity for ſuppoſing a gradual Decay of Moiſture in any of the Planets. Beſides, if the Comets were intended to ſupply the Planets with Moiſture, none of them could ſerve for this Purpoſe more than once, but muſt afterwards become uſeleſs, tho’ they return regularly in their Orbits, which is not agreeable to the Œconomy of Nature. For when the Heat of the Sun had driven all the Moiſture it could from a Comet in its *Perihelion*, where ſhould it afterwards get a freſh Supply? We can ſcarce ſuppoſe the Planets to loſe any Moiſture by Evaporation, as no Vapours can riſe above their Atmoſpheres. Or even if any very thin Vapours, Steams or Effluvia of a moiſt Nature ſhould ariſe from them, they could not have Heat and Elaſticity enough to expand themſelves very far. But the electric Matter, from its vaſt ſubtilty and velocity, ſeems capable of making great Excurſions from the planetary Syſtem, and therefore the ſeveral Comets in their long Excurſions from the Sun, in all Directions, may overtake this Matter; and attracting it to themſelves may come back replete with it, and being again heated by the Sun, may diſperſe it among the Planets, and ſo keep up a Circulation of this Matter, which we have Reaſon to think is neceſſary in our Syſtem.

---

† *Philoſ. Tranſactions*, No. 253.

‡ *Elements of Chymiſtry*. Part 2d.

Sir *Iſaac*, after giving his Opinion that the aqueous Particles thrown off from Comets are taken up by the Planets as a ſupply of Moiſture adds: 'I 'ſuſpect moreover, That that Spirit which 'is the leaſt, but the moſt ſubtile and 'the beſt Part of our Air, and is ne'ceſſary for ſupporting the Life of all 'Things, comes chiefly from the Co'mets'‡ which ſhews that he thought the Tails of Comets might conſiſt of ſomething more than watery Clouds and Vapours. What he meant by theſe Words I cannot ſay, but I think they are extremely applicable to that kind of Matter which I have ſuppoſed comes to us from the Comets; and with which our Air generally abounds.

I ſhall now recapitulate, in a few Words, the Subſtance of what has been ſaid. As the Tail of a Comet, tho' exceedingly rare, yet meets with no Reſiſtance in its rapid Motion round the Sun, (except ſo ſlight a one as can only cauſe a very ſmall Condenſation on that Side of it which moves foremoſt, and thereby may make it a little brighter than the other Side) it cannot poſſibly move in a *Medium* denſer and heavier than itſelf, and therefore cannot be raiſed up from the Sun by the ſuperior Gravity of ſuch a *Medium.* And ſince the Tail is not capable of reflecting or refracting the Light of the Stars, it cannot ſhine by reflecting the Sun's Light; and conſequently does not conſiſt of Clouds or aqueous Vapours, but is itſelf a ſhining Subſtance, the nature of which it is the buſineſs of Philoſophers to diſcover. And from what Aſtronomers ſay of the Splendor of Comet's Tails, I am perſuaded they do not ſhine with ſuch a dull Light, as would be reflected to us by the Clouds or Vapours at ſo great a Diſtance, but with a briſker, tho' a glimmering Light, ſuch as would ariſe from a very thin volatile burning Matter. And here I muſt not omit an Obſervation of Dr. *Halley*'s, which ſeems very much to my Purpoſe. In his Deſcription of the remarkable *Aurora Borealis* ſeen in *England* in the Year 1716, (which I mentioned before) ſpeaking of the great Streams of Light, he ſays: *They ſo much reſembled the long Tails of Comets, that at firſt Sight they might well be taken for ſuch.* And afterwards, *This Light ſeems to have a great Affinity to that which the Effluvia of electric Bodies emit in the Dark.*†. From whence we find that this accurate Obſerver perceived a Reſemblance between thoſe Subſtances that I have been comparing together. Now I have ſhewn that they agree remarkably, not only in their Appearance, but alſo in ſuch Properties as we can obſerve in each of them, and therefore I have ſuppoſed them to be Subſtances of the ſame Nature. I have alſo endeavoured to ſhew that the electric Matter, from its known Properties, is capable of exhibiting to us all the Phænomena of Comet's Tails, and that we may from thence aſſign the Uſe of Comets with more Probability than has hitherto been done.

---

‡ Porro ſuſpicor Spiritum illum qui Aeris noſtri pars minima eſt, ſed ſubtiliſſima & optima, & ad rerum omnium vitam requiritur ex Cometis præcipue venire.

*Principia*, Pag. 515.

---

† *Philoſ. Tranſactions*, No. 347.

I have been leſs ſcrupulous of propoſing ſuch Conjectures as occurred to me concerning the Subſtance that forms the Tail of a Comet, as I conſidered that though they ſhould hereafter appear groundleſs, as very poſſibly they may, yet others by examining them, and comparing them with future Experiments and Obſervations, may probably be led to the Diſcovery of ſomething on this Subject that will be more ſatisfactory. And I think every Hypotheſis relating to the Effects of the electric Matter, if at all plauſible, may have its Uſe, by inducing us to make further Enquiries into the Nature and Properties of that Kind of Matter, from a Knowledge of which I ſuſpect our future Improvements in Natural Philoſophy will chiefly ariſe; eſpecially in that Part of it which relates to Fire and Heat, the Nature of which is at preſent but little known.

◆